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SHALL WE USE NATURAL ROCK PHOSPHATE OR MANUFACTURED ACID PHOSPHATE FOR THE PERMANENT IMPROVEMENT OF ILLINOIS SOILS?

By Cyril G. Hopkins, Chief in Agronomy and Chemistry

The following inquiry is made by Mr. F. I. Smucker, Bureau County, Illinois:

"On a recent visit through Armour's packing house the writer was handed the little booklet "Raw Rock Phosphate", which I am sending you under separate cover. To read it is not very encouraging to the reader as he had just about decided to try about 10 or 15 tons of rock phosphate. If it is a good thing why does an establishment like Armour's assist in denouncing it?"

The pamphlet referred to was published some six months ago by the National Fertilizer Association, reproduced in the "American Fertilizer" for August, 1908, and again in part in "Armour's Farmer's Almanac" for 1909. Because it deserves to be read by every man who has any interest direct or indirect in the subject of soil preservation, it is here reproduced in full as follows:

RAW ROCK PHOSPHATE

"FLOATS"

Published by the National Fertilizer Association

For years the raw rock question has cropped out spasmodically, in different parts of the world, like the measles or some other affliction.

Sometimes it was the result of the recommendation of some impractical theorist who occupied a position that brought him before the farmer —oftener it was foisted on an unsuspecting farming community by some one who was either directly or indirectly interested in an off-grade phosphate mine, and who used his official position to further the interests of the rock mine at the expense of the farmer.

But no matter what started its use the result has always been the same—no benefit derived from its use—a distrust of legitimate fertilizers, and a distinct set-back to agricultural interests which has taken several years to overcome.

In the following pages we give you the opinions of foreign experiment station men as well as those of our own country.

Both statistics and your good common sense tell you that the older the state or country the more fertilizers are used and the greater knowledge they have of their use.

The mere fact that in these older communities, both abroad and in this country, the use of legitimate fertilizers has increased rapidly from year to year for a hundred years conclusively shows their value.

The fact that wherever raw rock has been used its use has been abandoned, shows its worthlessness.

Read what authorities who know have to say on this subject:

RESOLUTION, passed by the Association of German Agricultural Experiment Stations, in Congress assembled, September 14, 1907, at Dresden, Germany:

"As a result of the extensive advertising which is done by certain parties advocating the use of RAW PHOSPHATE, the association passed the following resolution:

"THE ASSOCIATION HAS CONCLUDED, FROM FERTILIZER EXPERIMENTS AT HAND WITH RAW PHOSPHATE FERTILIZER, THAT THERE IS SHOWN NO PROFITABLE FERTILIZER EFFECT, APART FROM THOSE OF ACID SOIL. IN CONSEQUENCE THEREOF THE ASSOCIATION FEELS IT SHOULD DISCOURAGE THE USE OF RAW PHOSPHATE ON OTHER SOILS."

See 67th volume (5-6) page 329—

"Landwirtschaftlicher Versuchs Station."

The Association of German Agricultural Experiment Stations represents the highest authority on agricultural matters in Germany, and undoubtedly the best in the world.

German investigators, particularly Dr. Von Liebig, were the authors of most of the fundamental principles underlying fertilization and agriculture—and it is to them that we largely owe the progress made in this direction.

In view of the well-known thoroughness of German agricultural investigators, and the fact that the Association of German Agricultural Experiment Stations is universally regarded as the world's highest authority on

such matters, their opinion on the use of RAW PHOSPHATE as a fertilizer is of great importance to the American Farmer.

On account of the high price of land in Germany, intensive farming is everywhere practiced. The farmers there must—of necessity—use fertilizer containing plant food in available condition. Their selection of fertilizers is based on innumerable experiments covering over a hundred years.

The difference in crop yields per acre in Germany as compared with the United States is conclusive evidence of the soundness of their methods of fertilization. The average wheat yield per acre in Germany for the ten years, 1895 to 1904, inclusive, was 27.2 bushels, as compared with 13.4 bushels in the United States for the same period. On oats the yield per acre in Germany was 46.0 bushels, as compared with 29.2 bushels in the United States for the same period. (See pages 671 and 678, "Statistical Matter", reprint from Year Book of Department of Agriculture for 1905).

The soils of Germany have been cropped for hundreds of years, while a large portion of those in this country are virgin or comparatively fresh. Proper fertilization is the secret of the higher yield per acre in Germany. If the United States is to maintain its supremacy in agriculture, farmers in this country will have to properly fertilize their crops—and they can well take heed to the experience of their German brothers in this respect.

Before using raw rock, therefore, you would do well to ascertain its true fertilizing value—the availability of the plant food it is supposed to contain—and especially to consider the decision of the German experimenters after years of careful testing.

From the standpoint of furnishing available plant food RAW ROCK PHOSPHATE is not a fertilizer. The report of the twenty-fourth annual meeting of the Association of German Agricultural Experiment Stations at which the resolution quoted was passed, states that from "real, exact experiments", conducted by such authorities as P. Wagner, Tacke, Bottcher, Lemmermann and others, "but little fertilizing effect was shown."

Further experiments made by Czerhati, L. Rey, Clausen and others, led to similar results just stated.

The same report states that, "From the present experiments it can be concluded with certainty that the general use of earthy phosphates (RAW ROCK PHOSPHATE) cannot be considered as phosphoric acid fertilization". Phosphoric acid is the only element this material contains, and if IT is NOT available it is useless for fertilizing purposes.

The experiment station officials of Germany have gone on record against the use of RAW ROCK PHOSPHATE in no uncertain tone. Their opinion is shared, with but one or two exceptions, by all the experiment stations in this country. If THIS material cannot be recommended for German soils, where proper fertilization has been studied for so many years, is it not folly to attempt its use on the comparatively fresh soils of this country?

This report also refers to some recent experiments conducted by parties endeavoring to promote the sale of raw rock phosphate in Europe. In commenting on the so-called tests or experiments, the German report states—that they "were carried out with but very little exactness". They further class these experiments as "entirely unfounded, have been rejected by scientific agriculturists, and especially by Wagner, Tacke and Bottcher, in a manner not to be misunderstood".

The said representations of these promoters are classed as "A very serious deception", and misleading to the farmers.

The efforts to promote the sale of RAW ROCK PHOSPHATE in this country—in light of the world-wide failure to show any appreciable fertilizing effect—can only be classed, in the language of the German experimenters, as "A very serious deception," and misleading to the farmers.

Not alone in Germany have experiments with RAW ROCK PHOSPHATE proven very unsatisfactory. England has had equally as unsatisfactory results. Prof. F. H. Storer, in volume I of his book "Agriculture" —in speaking of the value of raw rock phosphate USED IN CONNECTION WITH MANURE, as compared with superphosphate, says, "This question would seem to have been answered long ago, in so far as good land is concerned, by the common English practice of using superphosphates".

Again, later, in comparing the effects of the same materials for fertilizing purposes in European countries, he says, "For Europe at least, i. e. for fertile districts, the question has been decided fully long ago and most emphatically in favor of superphosphate. It has been decided by the long continued experiments of a multitude of farmers and their conclusion has been plainly expressed by the ever increasing demand for superphosphate".

Coming down to our country, we find that experiments with RAW ROCK PHOSPHATE—with scarcely any exception—have proven unsatisfactory.

Experiments conducted by the Maine Experiment Station, covering several years on various crops, designed to show the relative availability of phosphoric acid as supplied in Acid Phosphate, Floats (Raw Rock Phosphate) and Redonda Phosphate, were summarized as follows:

"In every case the acid rock (Acid Phosphate) gave the best returns. The gain was especially marked with the family Gramineae, three members of which (barley, corn and oats) yielded nearly double the amount produced by Floats or Redonda. The effect upon sunflowers and buck-wheat was equally marked. If we compare the amount of dry matter produced by the acid rock with that produced by the Floats for all crops grown, we find the balance in favor of the acid rock to be FIFTY-TWO PERCENT. In other words—the effect of the available phosphoric acid as compared with the insoluble phosphate was to increase the product MORE THAN ONE-HALF."

The Georgia Experiment Station, commenting in Bulletin No. 2, concerning field experiments with phosphates and Kainit applied to cotton, states: "Of phosphate, Acid Phosphate appears to lead, slag comes next and the FLOATS ARE LAST".

A later Georgia bulletin (No. 31) in reviewing a comparison of superphosphate with Tennessee soft phosphate, states: "Superphosphate in a complete fertilizer was compared with one, one and a half and two times the same amount of Tennessee soft phosphate. The latter (Tennessee soft phosphate) was applied in each case at a loss".

In the Annual Massachusetts Experiment Station Report for 1902, concerning an experiment with various kinds of phosphates which were applied in equal amounts of phosphoric acid, there is the following regarding Raw Rock Phosphates: "Tennessee phosphate and Florida soft phosphate gave results very much inferior to all the others". This was an experiment on onions.

In the Massachusetts annual report for the following year (1903), con-

cerning the same experiment continued on cabbages, the previous year's results are confirmed:

"That Tennessee phosphate and Florida soft phosphate proved very much inferior to all others—"

In Scott County, Indiana, an experiment to determine the relative value of Raw Rock Phosphate and Acid Phosphate was started in 1904 and continued for four years. Equal values of Rock Phosphate and Acid Phosphate were applied in ONE application the first year—corn and wheat alternating. The actual amount of plant food applied was 286 lbs. total phosphoric acid in the Rock Phosphate, and 100 lbs. phosphoric acid in the Acid Phosphate. There were three plots in the experiment—one fertilized with Rock Phosphate, one with Acid Phosphate, one unfertilized. Notwithstanding the fact that the first year's corn crop was a total failure on all plats, the result on wheat showed a gain of fourteen bushels per acre with Acid Phosphate as against only nine bushels for the Rock Phosphate over the unfertilized plot. The profit per acre in four years from Rock Phosphate was $11.55; the profit in four years from Acid Phosphate was $13.50.

In Marion County, Indiana, another experiment for the same purpose was started and crops harvested for two years. Only one application of fertilizer was made, the entire amount being applied the first season. As in Scott County, equal values of Rock Phosphate and Acid Phosphate were applied. The results speak for themselves, and they are given in the table below as taken from Circular No. 10 of the Indiana Experiment Station. The yields are given in bushels per acre:

Amount Per Acre	Corn 1904	Wheat 1905
Unfertilized	20	3
Rock Phosphate, 1,000 lbs	20	6
Acid Phosphate, 715 lbs	27	16

The value of the increase per acre, figuring corn at 35 cents and wheat at 80 cents per bushel, on the plat fertilized with Acid Phosphate, was		$12 85
Deducting cost of Acid Phosphate		5 00
Net return on the increase		$ 7 85
Value of the increase with Rock Phosphate		$2 40
Deducting cost of Rock Phosphate		5 00
Or a net loss of	$2 60	per acre
On the total yields the results were as follows—		
Unfertilized	$ 9 40	per acre
*Raw Rock Phosphate	6 80	per acre
*Acid Phosphate	17 25	per acre

These figures show that the Rock Phosphate was applied at a dead loss of $2.60 per acre—the unfertilized yield value being $2.60 per acre more than the Rock Phosphate. The yield with Acid Phosphate was $7.85 more than the UNFERTILIZED, and $10.45 per acre more than the RAW ROCK PHOSPHATE. These results are from experiments primarily intended to show the value of the Raw Rock as a fertilizer. They are self-explanatory and

*Cost of Rock Phosphate and Acid Phosphate deducted.

show conclusively the FOLLY OF CONSIDERING THIS MATERIAL AS A FERTILIZER. Furthur, these results were obtained from 100 pounds of phosphoric acid in Acid Phosphate as compared with 286 pounds in raw rock phosphate.

The practical farmer, interested in the proper use of commercial fertilizers, can easily figure—that where Acid Phosphate gave such remarkable returns on experiments covering a series of years—it will pay him a handsome profit to invest judiciously in fertilizers every year giving such good returns.

Tennessee has some of the largest phosphate deposits in the world. In this state, where the value of phosphate is so well understood, Prof. C. A. Mooers, chemist and agronomist of the Agricultural Experiment Station at Knoxville, in a recent letter to THE AMERICAN FERTILIZER, has the following to say with regard to the use of this material in its crude state:

"A bill was introduced in the Legislature just adjourned to allow the sale of ground phosphate rock as a fertilizer. In presenting this matter to the Agricultural Committee the Commissioner of Agriculture and myself took the position that it would not be desirable to tag this material, as that would to a certain extent stamp it with the State's approval..... Our position is better understood when it is considered that a very large part of the fertilizers used in this State are for wheat, and, as is well known, RAW PHOSPHATE ROCK, as ordinarily used, GIVES NO RETURNS ON THIS CROP. Other large amounts are used, especially in West Tennessee, by the truckers, and for garden crops also RAW PHOSPHATE WOULD BE INADVISABLE. Fertilizers have been used in this State for many years, but our farmers have not studied the matter to any great extent, so that many of them would buy a fertilizer just BECAUSE IT WAS CHEAP, especially if it had the State's tag on it.

"Our results on leguminous crops, which are supposed to be better able to make use of the so-called insoluble forms of phosphoric acid than others, do not warrant the general use of RAW PHOSPHATE. I have recently corresponded with a number of station men who are interested in the use of fertilizers, and I find that the general opinion is AGAINST THE USE OF THIS MATERIAL, although under special conditions, such as are found on a decidedly acid soil, its use may be advisable."

The State of Alabama is one of the oldest of the States using commercial fertilizers. Bulletin No. 24, issued May 15, 1908, contains an article on "Raw Phosphate Rock as a Fertilizer." Following are extracts from this article:

"Many parties have written to this office for information as to the relative fertilizing value of the Raw Phosphate, as compared with the acidulated phosphates, and the writer has invariably advised caution in the employment of this particular kind of phosphate.

"The samples of this material which have reached this laboratory have almost invariably exhibited a poor mechanical condition, the particles being coarse and irregular in size. As the fineness of division of this phosphate has a most important influence upon its availability to the plant, purchasers of this material have been advised to only use the rock which has been pulverized to a state of practical impalpability, the material in this condition being commonly designated by the name of "floats."

"A typical analysis of the Raw Phosphate Rock sent to this laboratory this season is given herewith:

Citrate Soluble Phosphoric Acid.....	0.68	per cent
Acid Soluble Phosphoric Acid.....	23.55	per cent
Total Phosphoric Acid.....	24.23	per cent

"It will be noted that nearly all of the phosphoric acid in this phosphate is in an insoluble or acid soluble condition, and there IS SCARCELY A TRACE OF WATER SOLUBLE PHOSPHORIC ACID TO BE FOUND IN THIS RAW PHOSPHATE.

"With regard to the comparative availability of Raw Phosphate Rock, it might be stated that the Experiment Station at Auburn has, during the past few years, carried out under its supervision more than one hundred cooperative soil and crop tests in a great many different localities in the state with a view to determining the comparative efficiency of Raw Phosphate and Acid Phosphate for fertilizing purposes. These tests have been carried out upon quite a variety of soils, and upon most soils the RAW PHOSPHATE HAS FAILED TO GIVE ANYTHING LIKE SO GOOD RESULTS AS THE ACID PHOSPHATE.

"In the case of Acid Phosphate, the ready solubility of most of the phosphoric acid contained therein promotes its rapid and thorough distribution through the top layer of the soil, and hence the plant food is so well disseminated that it is brought within easy reach of the root system of the plant, whereas in the case of the crude insoluble phosphate the diffusion and distribution of the phosphoric acid is necessarily slow, and much of the phosphate is left unutilized at the end of the season in which it is applied.

"For the above reasons IT IS DEEMED INADVISABLE TO EMPLOY THE CRUDE PHOSPHATE to any great extent upon any given soil until comparative tests of the crude rock and acid phosphate have been made upon that soil, and, even under these conditions, it will probably be found necessary to use much larger amounts of phosphate rock than are ordinarily employed to secure a satisfactory return from its application."

While the experience of the German Experiment Stations, combined with a majority in this country, show emphatically that Raw Rock Phosphate has little or no fertilizing value, in addition the method of applying followed by users of this material in this country is MOST EXTRAVAGANT AND WASTEFUL. The method followed would soon exhaust the known or visible supply of phosphate rock. Further, the enormous quantities necessary to apply per acre, instead of being scattered over and benefiting millions of acres, would be wasted on comparatively a few.

On the other hand, this crude material when properly treated with sulphuric acid and converted into Acid Phosphate, to be used either as straight Acid Phosphate or in mixed fertilizers, becomes a source of available plant food of greatest value. Raw Rock Phosphate, as mined and sold by certain operators, does not contain plant food immediately available to growing crops. It is only by proper handling and treatment with sulphuric acid that this material is converted into fertilizer furnishing plant food available to various crops and soils.

Reputable fertilizer manufacturers decry the use of Raw Rock Phosphate as a fertilizer, knowing that its use will NOT prove satisfactory, as borne out by extensive experiments of the world's best agriculturists. They have gone on record against its use, and any lack of results on the part of those using this material should not vitiate against the use of com-

mercial fertilizers rightly prepared, furnishing available, nourishing plant food for all crops. [SIGNED]

THE NATIONAL FERTILIZER ASSOCIATION.

With this complete statement before us, I shall undertake to answer Mr. Smucker's inquiry referred to me by the Breeder's Gazette.

The primary purpose of this inquiry, as I understand it, is for specific information concerning the use of raw rock phosphate for soil improvement; and second to this is the question relating to the opposition to its use of such an establishment as Armour's.

First, I may say that I have no financial interest, direct or indirect, in any phosphate enterprise, except in the use of natural rock phosphate upon my own Illinois farm; and for this use I have purchased phosphate from four different phosphate companies. No phosphate stock, bonds, or contracts, definite or implied, are owned or controlled by me or for me in any manner whatsoever. (See Illinois Circular No. 97, August, 1905).

The University of Illinois Agricultural Experiment Station teaches that raw rock phosphate is the most economical and profitable form of phosphorus to use in systems of permanent agriculture for most soils of this state. This teaching is not based upon any man's opinion, but upon the existing facts, which anyone may examine for himself.

We recognize the German Association of Agricultural Experiment Stations as high authority along most lines of agricultural investigation, but unfortunately the "fertilizer experiments *at hand* with raw rock phosphate" in Germany are extremely limited, and, while the conclusion drawn by the German Association from such experiments as have been made in Germany with raw rock phosphate might be justified, that Association has certainly failed to recognize the fact that the only truly valuable agricultural investigations with fine-ground natural phosphate as a source of phosphorus have been conducted by the Experiment Stations of the United States. A careful review of European agricultural literature fails to reveal any investigations more satisfactory than a few pot culture experiments, or field experiments covering one or two years, and rarely, if ever, conducted in what must now be considered the only rational way, namely by providing sufficient decaying organic matter to render the phosphate available as needed by the growing crops.

The possibility of German investigators sometimes drawing incorrect conclusions because of insufficient data is well illustrated

in the discussions concerning the sources of fat in the animal body. See, for example, pages 231 to 282 of Bulletin 22, Office of Experiment Stations, U. S. Department of Agriculture, "Agricultural Investigations at Rothamsted, England, during a Period of Fifty Years", by Sir J. Henry Gilbert.

Seven different Experiment Stations in the United States have carried on extensive and long continued investigations with the use of fine-ground natural rock phosphate. These are Ohio, Maryland, Pennsylvania, Maine, Massachusetts, Rhode Island, and Illinois. Twelve years' results are reported by the Ohio Station, 12 years' by the Pennsylvania Station, 12 years' by the Maryland Experiment Station, 11 years' by the Rhode Island Station, 14 years' (in two series) by the Maine Station, 21 years' (in two series) by the Massachusetts Experiment Station, while the Illinois Experiment Station has five years' results from a large number of experiment fields in many different sections of the state.

The published reports from any one of these seven different Experiment Stations furnish more information concerning the practical use of raw rock phosphate than is revealed in all European literature, and it is at least noteworthy that this pamphlet published by the National Fertilizer Association contains absolutely no mention of the work done by five of these states, and it is also noteworthy that the pamphlet fails to tell the whole truth concerning the work done by the Experiment Stations from which it quotes.

For example, the quotation from the Maine Experiment Station beginning with the statement, "In every case the acid rock (acid phosphate) gave the best returns", is taken from page 72 of the 1898 report of the Maine Experiment Station; whereas on page 57 of the 1900 report of the Maine Experiment Station occurs the following statements:

"For the first year the largest increase of crop was produced by soluble phosphoric acid. For the second and third years without further addition of fertilizers, better results were obtained from the plots where stable manure and insoluble phosphates had been used."

And on page 58 of the same report is added the following:

"The phosphoric acid of bone and South Carolina rock was quite freely appropriated by oats, peas, and corn."

As a matter of fact the Maine Station reports two series of experiments with different phosphates, one covering a period of nine years with all tests in triplicate on twentieth-acre plots where equal amounts of phosphorus were compared, and the other

for five years on 2½-acre plots where equal money values of phosphorus were compared. In the nine years' experiments the raw phosphate produced only about one-half as much increase as the other forms but at less than one-third the cost and with no adequate provision for decaying organic matter, without which the raw phosphate is not expected to become available, a point which has been emphasized again and again especially by the Illinois Experiment Station and by the agricultural press of the central west.

Thus the following statement has appeared in print so frequently that people who are interested in the subject must almost know it by heart:

"As to the value of non-acidulated finely ground natural rock phosphate, I consider this as a material which gives great promise of extensive use in the economic and profitable improvement of poor soils and in the maintenance of large crop yields on good soils, especially in the states throughout the great central west. It should be distinctly understood, however, that repeated experiments have shown that this material gives practically no immediate returns if used in the absence of decaying organic matter. On the other hand, when used in intimate connection with liberal amounts of farm manure or green manures or both, we have conclusive evidence that it is one of the most economical and profitable forms of phosphorus, especially where the crop returns for a series of years are to be taken into account."

In the other series of phosphate experiments at the Maine Station the data show that during the first two years after application the acid phosphate gave about the same results as the raw phosphate, but afterward the raw phosphate gave distinctly better results than the acid phosphate. In commenting upon these results Doctor Jordan, then Director of the Maine Station, said:

"With the exception of the wheat crop of 1891 the production of plot 2 (raw phosphate) has largely exceeded that of plot 3 (acid phosphate). Especially is this true of the 1894 crop after the exhaustive effect of three years of cropping * * * * This is certainly one instance of the unmistakable influence of a crude phosphate in increasing the growth of a field crop."

The two quotations from the Massachusetts Experiment Station relating to the onion crop in 1902 and the cabbage crop in 1903 have little or no bearing upon questions of general farming. In market gardening very large quantities of expensive fertilizing materials supplying readily available plant food can usually be used with large profit. Moreover most garden crops are highly developed and may be considered extremely artificial plants, accustomed to the richest soil, where instead of developing any power to forage for themselves they are in a sense

"stuffed" with all of the available plant food they can possibly utilize.

The artificial development of these plants is well illustrated by the cabbage and the turnip, which are believed by most botanists to have come originally from the same plant, and it is known positively that cabbage and cauliflower were derived from the same plant. It is notorious that plants of the cabbage family have almost no power to secure phosphorus from insoluble phosphates. This fact was demonstrated seventy years ago by Sir John Lawes at the now famous Rothamsted Experiment Station, the oldest in the world.

But the pamphlet from the Fertilizer Association does not tell the whole truth concerning the investigations of the Massachusetts Station. The onion crop in 1902 was extremely unsatisfactory. The plots which received no phosphorus whatever varied in yield from 26.2 bushels to 195.7 bushels per acre, while the plot to which acid phosphate was applied produced only 159.4 bushels. Furthermore, onions were also grown in 1901, when the average yield from three insoluble phosphates was 197.2 bushels, the highest of these three being 235.4 bushels, whereas the average yield from three plots treated with different forms of soluble phosphorus was 203.5 bushels, and of these three the acid phosphate plot itself was the lowest one, yielding only 187.8 bushels, or less than the average of the three insoluble phosphates. Furthermore these quotations refer to an experiment in which equal amounts of phosphorus were applied, altho the phosphorus in acid phosphate cost three or four times as much as that in raw phosphate.

As a matter of fact, the Massachusetts Station has reported the results of an experiment extending over eleven years in which equal money values of different phosphates were used. The yields of fourteen different crop products are reported from this investigation, including grain, straw, etc. The only phosphates tested during the entire period were slag phosphate, guano phosphate, South Carolina rock phosphate, and acid bone black (acidulated or dissolved bone black). The latest summary of these investigations reported by Doctor Brooks, Director of the Massachusetts Station, gives these phosphates the following rank for the entire period.

Slag Phosphate	100.0
Ground South Carolina Rock	92.3
Dissolved Bone Black	90.7
Guano Phosphate	88.3

For the later years Doctor Brooks ranks them according to yield as follows:

South Carolina Rock Phosphate.....	100.0
Slag Phosphate	99.0
Dissolved Bone Black.....	97.7
Guano Phosphate	95.4
No Phosphate	55.4

In commenting upon these experiments Doctor Brooks says:

"The following conclusions appear to be justified by the results which we have obtained:

"It is possible to produce profitable crops of most kinds by liberal use of natural phosphates, and in a long series of years there might be a considerable money saving in depending at least in part upon these, rather than upon the higher priced dissolved phosphates."

"Between ground South Carolina rock, mono guano, and the phosphatic slag, there is no considerable difference in the economical result".

The two investigations by the Georgia Experiment Station referred to in the Fertilizer Association's pamphlet are each the result of a single year's experiment and with no adequate provision for decaying organic matter, and hence, like some of the German experiments, have practically no value as evidence in relation to permanent systems of soil improvement. It should always be kept in mind that a quotation taken from its connection may be very misleading. Thus an Experiment Station bulletin may contain a statement that raw phosphate was very inefficient as a source of phosphorus, which might perhaps refer only to a crop of cabbage grown in a poor year and on soil containing no adequate supply of organic matter; but to take such a statement from its limited connection and make it appear as the final conclusion of the Experiment Station concerning the use of raw phosphate would very possibly mislead.

The experiment reported from Scott county, Indiana, has some meaning, because there was nearly as large an investment in the raw rock as in the acid phosphate and the experiment has been continued for four years; and a profit from the raw rock of $11.55 per acre in four years is surely quite satisfactory compared with $13.50 from the acid phosphate, when we consider that about two-thirds of the raw rock phosphate will remain in the soil after the acid phosphate is completely exhausted, and also considering that there was one crop failure during the four years. The whole truth concerning this experiment is not reported, however, in the Fertilizer Association's pamphlet. The fact is that the yield from acid phosphate exceeded that from raw phosphate only in the first wheat crop, while in the following corn crop the raw phosphate produced a greater yield by 5 bushels, and also 2 bushels more wheat in the succeeding year.

Referring to this experiment Director Goss, of the Indiana Experiment Station, says (Indiana circular No. 10, page 11):

"It will be seen that during the first and second years the rock phosphate produced little effect in either experiment (Marion county and Scott county), while the acid phosphate very materially increased the yields in both cases. During the third and fourth seasons, however, the rock produced very striking results in the Scott county experiment, even forging ahead of the acid.

"This and very similar investigations in progress lead us to believe that rock phosphate is a cheap and effective source of phosphorus where immediate returns are not required. Its use should be considered more in the nature of an investment than as a means of securing results in a single season, for which purpose it would undoubtedly prove disappointing. For quick returns, acid phosphate or some other readily available form should be used."

The experiment reported for Marion county, Indiana, has but little significance because only two years' results are given, and it is questionable whether this experiment deserves the expanded discussion occupying one and one-half pages in the Fertilizer Association's pamphlet.

I do not know what is meant by bulletin No. 24, issued May 15, 1908, by the State of Alabama but I do know that it is not bulletin 24 of the Alabama Agricultural Experiment Station, and I also know that Director Duggar, of the Alabama Station, advises the use of raw rock phosphate under proper conditions.

The quotation from Professor Mooers, of Tennessee, refers especially to the fertilizers used by the truckers for garden crops and to those used on wheat for immediate effect. Neither the Alabama or the Tennessee Station have reported any long continued investigations with the use of raw rock phosphate.

After twelve years' experiments with different forms of phosphorus at the Maryland Station, Director Patterson makes the following statements (Maryland bulletin 114):

"The results obtained with the insoluble phosphates has cost usually less than one-half as much as that with the soluble phosphates.

"The results show decidedly that plants are able to use insoluble phosphates.

"The use of an abundance of organic matter in the soil when insoluble phosphates are applied was evidently a necessity for their best effects.

"Insoluble South Carolina phosphate rock produced a higher total average yield than dissolved South Carolina rock."

The Pennsylvania Experiment Station has reported results of an experiment extending over twelve years in which four different kinds of phosphorus were used in a four-year rotation of corn, oats, wheat, and hay (timothy and clover); and at the end of the twelve years the following comments concerning these experiments were made by the Pennsylvania Station (annual report for 1895, page 210);

"The yearly average for the twelve years gives us a gain per year of $2.83 from insoluble phosphoric acid (ground bone), $2.45 from insoluble phosphoric acid (South Carolina rock), $1.61 from reverted phosphoric acid, and $.48 from soluble phosphoric acid, thus giving us considerably better results from the two forms of insoluble phosphate than from the reverted or soluble forms, thus indicating that the insoluble phosphate is of more value as a manure than is usually supposed and that it is worthy of more attention than has been given to it in the past."

During the last four years of these experiments the dissolved bone black increased the yield of corn by 7.9 bushels, the yield of oats by 2.8 bushels, and the yield of hay by .12 ton per acre, while the yield of wheat was actually decreased 1.2 bushels per acre. During the same time the raw rock phosphate increased the yield of corn by 8.6 bushels, the yield of oats by 8.4 bushels, the yield of wheat by 8.4 bushels, and the yield of clover by .20 ton, thus showing greater gain with every crop from the use of the raw rock. While the Pennsylvania Station used a good rotation it could not be expected to produce as satisfactory results as would have been secured with more adequate provision for decaying organic matter.

The Rhode Island Experiment Station has reported eleven years' results with a variety of crops, including several garden crops. In commenting upon these experiments, Director Wheeler makes the following statements in Rhode Island bulletin 114:

"With the pea, oat, summer squash, crimson clover, Japanese millet (on the unlimed land), golden millet, white podded Adzuka bean, soybean, and potato (on the unlimed land), floats gave very good results; but with the flat turnip, table beet, and cabbage they were relatively very inefficient."

"The use of fine-ground bone, basic slag meal, and floats has tended continually to make the unlimed lands more favorable to clover, as is well shown by its appearance only upon those plots of the unlimed series where these phosphates had been used, while it was absolutely lacking where the raw and roasted Redondite and the soluble phosphates had been applied."

"Floats can probably be used to best advantage on moist soil rich in decaying vegetable matter and for such crops as certain legumes, Indian corn, millet, and possibly wheat and oats, which seem far better able to make use of them than certain vegetables."

And again in Rhode Island bulletin 118 the following statements are made:

"Floats gave very good results from the soybean, peas, crimson clover, mangel-wurzel (on limed land), barley (on limed land), potato (on unlimed land), Japanese millet, oat, and golden millet, but they proved highly inefficient especially for Hubbard squash, ruta-baga, crook-neck squash, flat turnip, cabbage, mangel-wurzel (on acid unlimed land), tomato, lettuce, New Zealand spinach, and red Valentine bean."

These statements drawn from the data published show that

good results have been obtained from the use of raw rock phosphate at the Rhode Island Station for most of the ordinary general farm crops, while it has little value for most of the garden plants, particularly for those of the cabbage family. If we add together the total yields of grain and hay secured during the decade following the first year of the experiment at the Rhode Island Station we have the following results on unlimed land:

Soil Treatment	No Phosphate	Raw Phosphate	Acid Phosphate
Pounds per acre	8,310	22,890	22,860

These yields include the oats grain for 1895, ear corn for 1900, and soybeans (yield of seed only reported) for 1902, the yields of timothy and clover hay for the four years, 1896 to 1899, and the yield of oat hay for 1904. In 1901 and 1903 the plots were planted mostly in garden vegetables.

The corresponding figures for the limed plots are as follows:

Soil Treatment	No Phosphate	Raw Phosphate	Acid Phosphate
Pounds per acre	27,470	35,340	37,000

It will be seen that on the unlimed land the raw phosphate produced slightly better results than the acid phosphate, while on the limed land the acid phosphate produced 20 percent greater increase than the raw phosphate. These experiments were started with a comparison of equal money values of the different forms of phosphorus but were afterward changed to a comparison of equal amounts of phosphorus, so that before the close of the ten-year period from three to four times as much money had been invested in the acid phosphate as in the raw rock.

The experiments from Maine, from Massachusetts, from Maryland, from Rhode Island, and from Pennsylvania are certainly sufficient to show that fine-ground natural rock phosphate is a more economical source of phosphorus than acid phosphate for use in general farming in definite systems of soil improvement, altho if one's interests are limited to the first crop I should certainly advise him to use acid phosphate rather than the raw rock; and on soils very deficient in decaying organic matter I always advise the use of steamed bone meal or acid phosphate in preference to raw rock phosphate.

The fact should be emphasized that even tho these long continued experiments on different soils and in different states have given positive information they have not been conducted in a way to bring out the best results from the raw rock phosphate, because practically no provision was made for supplying decaying organic matter other than what was unavoidably left in the roots and stubble of the crops grown, aside from the work in Maryland where a few catch crops of crimson clover were plowed under.

Of greater value to Illinois agriculture perhaps than all of the work done in the five states mentioned are the investigations of the Ohio Experiment Station, which cover twelve years of undoubtedly as careful field experimentation as has ever been conducted. In these investigations three different and entirely distinct fields are used and in each field a double comparison has been made between raw rock phosphate and acid phosphate. A three-year rotation is practiced, consisting of corn the first year, wheat with clover seeding the second year, and the regular clover crop the third year, these crops being rotated so that every crop is represented every year.

In each field there are two plots that are treated with manure alone which is applied to the clover sod at the rate of 8 tons per acre and plowed under for corn, no further application being made for the wheat or clover. There are two other plots in each field treated with the same kind and amount of manure to which has been added 40 pounds of raw rock phosphate with each ton of manure, and there are still two other plots on which, likewise, the same quantity and kind of manure is used to each ton of which is added 40 pounds of acid phosphate.

The following tabular statement gives the average of all of the yields obtained during the 12 years for each field.

OHIO EXPERIMENTS WITH MANURE, RAW ROCK PHOSPHATE, AND ACID PHOSPHATE

Average of Twelve Years, With Duplicate Tests On Each Field.

Soil Treatment.	Field A	Field B	Field C	Average
Corn, bushels per acre				
Manure alone	47.2	63.6	53.3	54.7
Manure and rock phosphate	56.4	69.5	58.2	61.4
Manure and acid phosphate	54.6	70.8	62.0	63.1
Wheat, bushels per acre				
Manure alone	20.4	21.7	17.2	19.8
Manure and rock phosphate	23.4	30.4	24.6	26.1
Manure and acid phosphate	23.8	29.4	25.1	26.1
Clover hay, tons per acre				
Manure alone	1.99	1.34	.83	1.39
Manure and rock phosphate	2.47	1.90	1.79	2.05
Manure and acid phosphate	2.23	1.76	1.92	1.97

The first column of figures in the table gives, first the average yield of corn from the two plots treated with manure alone on field A (47.2 bushels), next in the same column the average yield of corn from the two plots treated with manure and raw rock phosphate on field A (56.4 bushels) and next in the same column the average yield of corn from the two plots treated with manure and acid phosphate on field A (54.6 bushels). Following these are reported the corresponding yields for wheat and for clover. In the next column are given the complete data for field B, and in the next column are likewise the complete data from field C, and in the last column are reported the averages for the three fields.

It will be seen that, as an average of all the data from the twelve years' experiments, the increase from the raw rock phosphate has been practically identical with that from the acid phosphate, while the cost of treatment was twice as great with the acid phosphate as with the raw rock. Furthermore, twice as much phosphorus has been applied in the applications of raw rock as in the applications of acid phosphate, so that at the close of the twelve years the raw phosphate plots still contain as much applied phosphorus as the total application made in the acid phosphate. It will be observed that in case of the clover crop, which has power to secure nitrogen from the air, or should have if the soil contains plenty of lime, the rock phosphate has produced distinctly better results than the acid phosphate, the average difference amounting to .08 of a ton per acre, or 64 cents' worth of hay at $8.00 per ton.

Fine-ground natural rock phosphate, carrying 12 to 12½ percent of the element phosphorus (corresponding to 60 to 62½ percent of so-called bone phosphate of lime), can be purchased from various mine owners in the Mt. Pleasant and Centerville districts of Tennessee for $3.50 to $4.50 per ton, and the freight rate from Mt. Pleasant or Centerville to central Illinois is $3.03 per ton of 2,000 pounds. Acid phosphate (with 7 percent phosphorus) will commonly cost from $15 to $18 per ton delivered in central Illinois.

Aside from all of the investigations reported from the six states mentioned, the Illinois Experiment Station has conducted extensive experiments with the use of raw rock phosphate on several separate experiment fields in different counties thruout the Illinois corn belt. These experiments have been in progress only five or six years but they are being conducted along lines of practical soil improvement, the nitrogen and humus being supplied by the use of clover and other legume crops and in

some instances by applications of farm manure. In all cases the same systems are practiced both without phosphate and with phosphate, so that there is always a direct comparison showing the influence upon crop yields of the phosphate applied.

Thus far the results secured in the Illinois investigations are entirely in harmony with those reported by the Ohio Experiment Station. But little effect is produced by the raw rock during the first year or two, but where it is used liberally it usually pays for itself during the first rotation, even though three-fourths of the phosphorus applied remains in the soil for the benefit of future crops and for the definite enrichment of the land. For example, as an average of 32 distinct and entirely separate tests conducted on eight different fields in six different counties, the average yield of corn in 1908 was increased 9 bushels per acre where raw rock phosphate has been used during the previous four or five years.

Mr. Smucker asks:

"If it is a good thing, why does an establishment like Armour's assist in denouncing it?"

There are perhaps four reasons that might be given in answer to this question.

1. There is probably more profit to the fertilizer manufacturer and dealer in the $30 received from the sale of two tons of acid phosphate (made from one ton of raw rock and one ton of sulfuric acid), and still more profit in perhaps $80 received from the sale of four tons of complete fertilizer (made from two tons of acid phosphate and two tons of filler, containing small amounts of nitrogen and potassium), than there would be in $6 or $8 from one ton of fine-ground natural rock phosphate, carrying the same amount of phosphorus.

That is to say, one ton of raw rock phosphate furnishes all of the phosphorus contained in about two tons of acid phosphate or in four tons of the most common "complete" fertilizer, for which the local price charged by Illinois dealers averages $23 per ton.

2. It is probable that some of the manufacturers and dealers in acid phosphate and complete fertilizers believe that raw rock phosphate is practically worthless for use as a fertilizer; and this is of course true for immediate results on most of the worn soils of the eastern and southern states, where fertilizers are most used.

3. Some who understand that raw rock phosphate can be used more economically than other forms of phosphorus, in connection with definite systems of soil improvement continued year

after year, are of the opinion that farmers do not and will not look beyond the first year's results, and that the only practical method of dealing with the farmer is to furnish him small amounts of readily available plant food which will perhaps give his crop an extra start in the spring and enable it to draw more heavily upon the soil than it otherwise would, thus using in the one crop more plant food than was applied in the fertilizer. Such a system appears to be profitable for the year, but in most cases it leaves the land poorer than at the beginning, so that ultimately the system of using small amounts of acid phosphate or so-called complete fertilizer tends toward land ruin.

4. Some men of large financial interests, who could wield large influence for good, evidently do not appreciate the fact that the greatest material problem of the United States is to bring about the general adoption of systems of farming under which the farm lands of this country will grow more productive, and that upon this depends the future success of every other important industry and the ultimate welfare of ourselves and our children.

In conclusion it should be said that no man or set of men should be allowed to control absolutely the great phosphate deposits of the United States. They constitute the key to permanent agriculture on all of the normal valuable agricultural lands of this country. We are already exporting a million tons of this material annually, for which we receive at the mine not more than six million dollars, while the additional corn that could ultimately be grown if that quantity of phosphate were applied to our own soils would be worth at least six hundred million dollars. Furthermore, when the phosphate is once applied to our soils it can be removed in crops and largely returned again to the soil in green manures, in farm manure, in bone meal, tankage, and other products, and thus used over and over again.

Phosphorus is already the element that limits crop yields on those great soil areas in the corn belt, in the wheat belt, and in the cotton belt, which are producing and must produce the great bulk of the crops required to feed and clothe the American people; and, in the conservation of our natural resources, the first duty of the United States is to insure not the conservation but the preservation of the fertility of these soils, which constitute our only protection against famine.

The supply of nitrogen in the air is absolutely inexhaustible; and the supply of potassium in all normal soils is also practically inexhaustible (potassium can also be recovered if necessary from the ocean's inexhaustible supply); and our deposits of limestone

are surely inexhaustible; whereas, our total supplies of phosphorus are extremly limited, not only in our most important soils, but also in our natural phosphate deposits, and phosphorus is not contained in the air or in the sea. According to the report of the National Conservation Commission, presented to the Conference of Governors and State Conservation Commissioners, at Washington, on December 9, 1908, the total supply of high-grade phosphate rock in the United States will be exhausted within from 25 to 50 years. After that we must draw on our more or less extensive low-grade deposits.

Already some of our most extensive high-grade deposits are said to be controlled by the Franco-American Phosphate Company, whose chief interest is evidently in the exportation of this tremendously important and absolutely necessary natural resource, the conservation of which is of the gravest and most far-reaching consequence to the United States.

According to the statistics published by the United States Geological Survey the total quantity of phosphate rock mined in the United States during the year 1907 was 2,265,343 tons, and the total value of this at the points of shipment was $10,653,558. Thus, according to these Government figures for both quantity and value, the phosphate was worth as an average $4.70 per ton of 2,240 pounds, or $4.20 per ton of 2,000 pounds. It should be understood, too, that most of the highest grade rock is exported.

The Government report shows that during the twelve months ending with June, 1908, the quantity of phosphate rock exported from the United States was 1,180,280 tons, and that the total value of this on ship board at points of shipment was $9,407,961, or, as an average, $7.97 per ton of 2,240 pounds, or $7.12 per ton of 2,000 pounds. The export rock contains, as a rule, 14 percent or more of the element phosphorus, corresponding to 70 percent of so-called "bone phosphate of lime."

In the interest of the whole people, The United States Government should not do less than to restrict the annual exportation to one million tons with a gradual reduction of perhaps one-hundred thousand tons a year, so that all exportation would be prohibited at the end of ten years; and the phosphate industry in this country should also be under sufficient governmental control to prevent exorbitant prices, in order that landowners may be encouraged to apply more phosphorus to their land than is removed in crops, so that American soils may grow richer and not poorer in this essential element, which is the master key to our continued national prosperity, for without agriculture America cannot live and prosper.

For more detailed information concering crop yields from different methods of soil treatment on Illinois soil experiment fields, comparative value of steamed bone meal and raw rock phosphate, the use of ground limestone, potassium salts, crop rotations, legume catch crops, farm manure, etc., see Bulletins 99, 115, 123 and 125 and Circulars 97, 108 and 116. These will be sent free of charge upon application to Director E. Davenport, Agricultural Experiment Station, Urbana, Illinois; and if requested the applicant's name will be placed upon the permanent mailing list for subsequent publications.

NOTES

Natural Rock Phosphate

Fine-ground raw rock phosphate, containing from 10 to 14 percent of phosphorus, can be obtained from the Mt. Pleasant Fertilizer Co., Mt. Pleasant, Tenn.; from Robin Jones, Nashville, Tenn.; from the N. Y. & St. L. Mining & Mfg. Co., St Louis Mo.; from the Swan Creek Phosphate Co., Chicago, Ill.; from the Jackson Phosphate Co., Mt. Pleasant, Tenn.; from the Farmers Ground Rock Phosphate Co., Mt. Pleasant, Tenn.; from John Ruhm, Jr., Mt. Pleasant, Tenn.; from H. D. Ruhm & Co., Mt. Pleasant, Tenn.; or from W. B. Alexander & Co., Mt. Pleasant Tenn.; delivered in bulk on board cars at the mines in Tennessee for $2.50 to $5.00 per ton, the price varying with the quality. The freight rate from Tennessee per ton of 2000 pounds in carload lots varies from $2.50 to points in Southern Illinois, to $3.58 to northern Illinois points. Of course, these addresses are given solely as a matter of information, but the Experiment Station makes no recommendations or guarantees as to reliability.

It should be borne in mind that rock phosphate varies much in quality. Consequently it should always be purchased upon a guaranteed analysis, and it is advisable for the purchaser to take an average sample of the carload when received and have it analyzed, even though it cost him $2.00 or $3.00 for the analysis. To collect an average sample, take a small teaspoonful from about fifty different places in the car, not only from the surface but also from different depths. These fifty spoonfuls well mixed together will make a trustworthy sample, and about one pound of this should be sent to some commercial chemist for analysis.

Sometimes the phosphate company and the purchaser agree upon some analytical chemist, and the sample is collected by the chemist or his agent just before the car is sealed, the report of the chemist being sent to both parties; and the agreement may be made so that the purchaser withholds part payment until he receives the chemist's report.

If 12½ percent rock, containing 250 pounds of phosphorus per ton, costs $7.50 (including freight), then 10 percent rock, containing 200 pounds of the element per ton, is worth $6.00, a difference in value of $1.50 per ton, which amounts to $45 on a 30-ton car of rock phosphate.

The important phosphorus compound in rock phosphate is calcium phosphate, $Ca_3(PO_4)_2$. The percentage of this compound in the rock phosphate marks the purity of the rock. Thus, if the rock phosphate con-

tains 60 percent of calcium phosphate, it is 60 percent pure, with 40 percent of impurities.

The natural rock phosphate deposits now being mined vary from about 50 percent to 70 percent, and we consider 62½ percent as a good average grade. The impurities consist of sand, shale, and other earthy materials naturally occurring in the phosphate deposits. The compound, calcium phosphate, is sometimes called bone phosphate, because it is the phosphorus compound in bone; it is also called lime phosphate, although it does not contain lime as such and has but little power to correct soil acidity; and in the wholesale trade this compound is called "bone phosphate of lime" (B. P. L.). It is important to know that this compound itself is absolutely constant and always contains exactly 20 percent of the element phosphorus, so that rock phosphate which contains "60 percent B. P. L." must contain 12 percent of phosphorus.

Sometimes the guarantee is given as "phosphoric acid", meaning phosphoric oxide, P_2O_5. This also is a definite compound and always contains 43⅝ percent of the element phosphorus. Thus, it will be seen that the same sample of rock phosphate may be guaranteed to contain 62 percent of calcium phosphate, $Ca_3(PO_4)_2$, or 28.4 percent of "phosphoric acid" (P_2O_5), or 12.4 percent of phosphorus (P).

Raw rock phosphate should be very finely ground, so that at least 80 percent of the material can be washed through a sieve with 100 meshes to the linear inch, or with 10,000 meshes to the square inch. Anyone can test for fineness by sifting 10 ounces and then drying and weighing what will not pass through the sieve.

As a rule it is most satisfactory to purchase in bulk rather than in bags (see Circular No. 110, page 15).

Bone Meal

A good grade of steamed bone meal (about 12½ percent phosphorus) can be obtained delivered in Illinois for about $25.00 a ton, from the local agents of Morris & Co., Swift & Co., the American Glue Co., or the Packer's Fertilizer Association, Chicago, Ill., or from Michigan Carbon Works, Detroit, Mich.

Potassium Salts

Potassium chlorid (so-called "muriate of potash"), containing about 42 percent of potassium, can be obtained for about $50.00 a ton from Armour & Co., Union Stock Yards, Chicago, Ill., from A. Smith & Bro., Tampico, Ill., or from American Agricultural Chemical Co., New York, N. Y. and kainit, containing about 10 percent of potassium in the form of potassium sulfate, together with some magnesium sulfate, magnesium chlorid, and sodium chlorid, can also be obtained from Armour & Co., and from Darling & Co., Chicago, Ill., for about $15.00 a ton.

Ground Limestone

Ground limestone can now be obtained at 60 cents a ton, (75 cents in bags, to be returned at purchaser's risk) from the Southern Illinois Penitentiary, Menard, Ill., and at different prices from Casper Stolle Quarry & Contracting Co., St. Louis, Mo., (quarry at Stolle, Ill.); Southwestern Contracting & Engineering Co., East St. Louis, Ill., Crystal Carbonate Lime Co., Elsberry, Mo., Carthage Superior Limestone Co., Carthage, Mo., Mitchell

Lime Co., Mitchell, Ind. Some of these companies furnish fine-ground limestone and some furnish limestone screenings, which include both very fine-dust and some coarser particles even as large as wheat grains. In carload lots the price on board cars at the plant varies from 50 cents to $1.00 a ton according to the fineness. The freight charges will vary from 50 cents or less to $1.50 or more, depending upon the distance. At most points in Southern Illinois the cost delivered in bulk in box cars should be between $1.00 and $2.00 a ton. The quickest action will be secured by using the finest material and mixing it most thoroly with the soil, but sometimes one can get one and one-half tons of material containing one ton of fine dust and half a ton of coarser particles, varying in size from less than pin heads to wheat grains, at no greater expense than would be required for one ton of fine-ground stone containing no coarser particles.